Voice Changer

An electronic circuit that can shift the pitch of your voice is called a voice changer.

Thanks to Holtek, there's an easy, inexpensive way to build a voice changing circuit: Use the HT8950A.

by Jack Dennon

Voice changing is an interesting application of electronics and could even have some important applications if you need, for example, to answer the phone without having your voice be recognized.

Voice changer circuits can be based on the frequency-shifting characteristics of the double balanced mixer (see sidebar) or, nowadays, you can take advantage of digital signal processing (DSP) techniques. Either approach involves a fair amount of design work. But thanks to Holtek, there is now an easier way to build a voice changing circuit: use the HT8950A.

This is actually a DSP-type approach, but you don't have to do any programming. Just add an LM386 audio output amp, a few passive components, and a nine-volt battery, and you have a system capable of shifting your voice up to sound like a lady, or down to sound like a gruff old man. There are six frequency shifts available, plus normal (no shift).

About the HT8950A

This Holtek HT8950A chip appears to simulate the operation of an audio tape recorder. But since it uses digital techniques, it can pull some tricks that would not be possible with physical tape. Mind you, I'm not certain that the way I will describe its operation is in fact what the chip actually does; Holtek's data sheet doesn't tell you exactly what is going on inside this chip.

We are told that there is an analog-to-digital converter at the input, a digital memory, and then a digital-to-analog converter for output. The actual algorithm may be quite sophisticated, but what it simulates is a tape recorder with variable speed readout.

So you can visualize it as an endless loop of tape, or a magnetic drum, with a write head that moves at about 8000 samples per second, and a read head that moves a selectable fraction or multiple of that rate.

For shifting up, you can select 4/3, 8/5, or two times the write rate; for shifting down you have available 8/9, 4/5, or 2/3 the write rate.

The chip was designed to be used in a handheld device. It has four pins internally debounced for dedicated push-button inputs. One of these inputs punches the pitch up one step, one punches the pitch down one step, and the other two invoke special effects that are a robot-like voice, and vibrato.

The chip powers up in the robot voice mode. The stepping up and stepping down provided by the two push-button inputs are each actually performed in a circular fashion.

In other words, you can get to any frequency shift by just punching the up button or the down button because when you hit the end of the multiplier table, they just wrap around to the other end of the table and keep stepping; the only difference between the two buttons is the direction in which they step. One goes clockwise, the other goes counter-clockwise, so to speak.

About the Circuit

The HT8950A operates on 2.4 to 4.0 volts and draws less than 10 milliamps so, as shown in Figure 1, we use a simple zener regulator to drop the voltage from a nine-volt battery down to our operating level.

Zener diode D1 draws just the right current through resistor R1 to maintain Vdd at about 3.5 volts. Pin 11 of the HT8950A — the "lamp" pin — draws current through LED D2 proportional to the audio level, so they say, but if you install resistor R10, then mainly it just shows that the power is on.

Resistors R7 and R8 set the internal clock rate. Resistors R9 and R5 establish the gain of the audio input amplifier. Resistors R4 and R6, with the help of smoothing capacitor C3, provide the bias voltage that the electret microphone requires.

Coupling capacitor C4 isolates the microphone's DC bias voltage from the IC's audio input amplifier while passing the audio voice signal.

The frequency-shifted audio available at pin 12 is low-pass filtered by R2 and C5 and then applied via pot R3 to the input of the audio output amplifier U2. The audio output amplifier is configured for a voltage gain of 20; out-

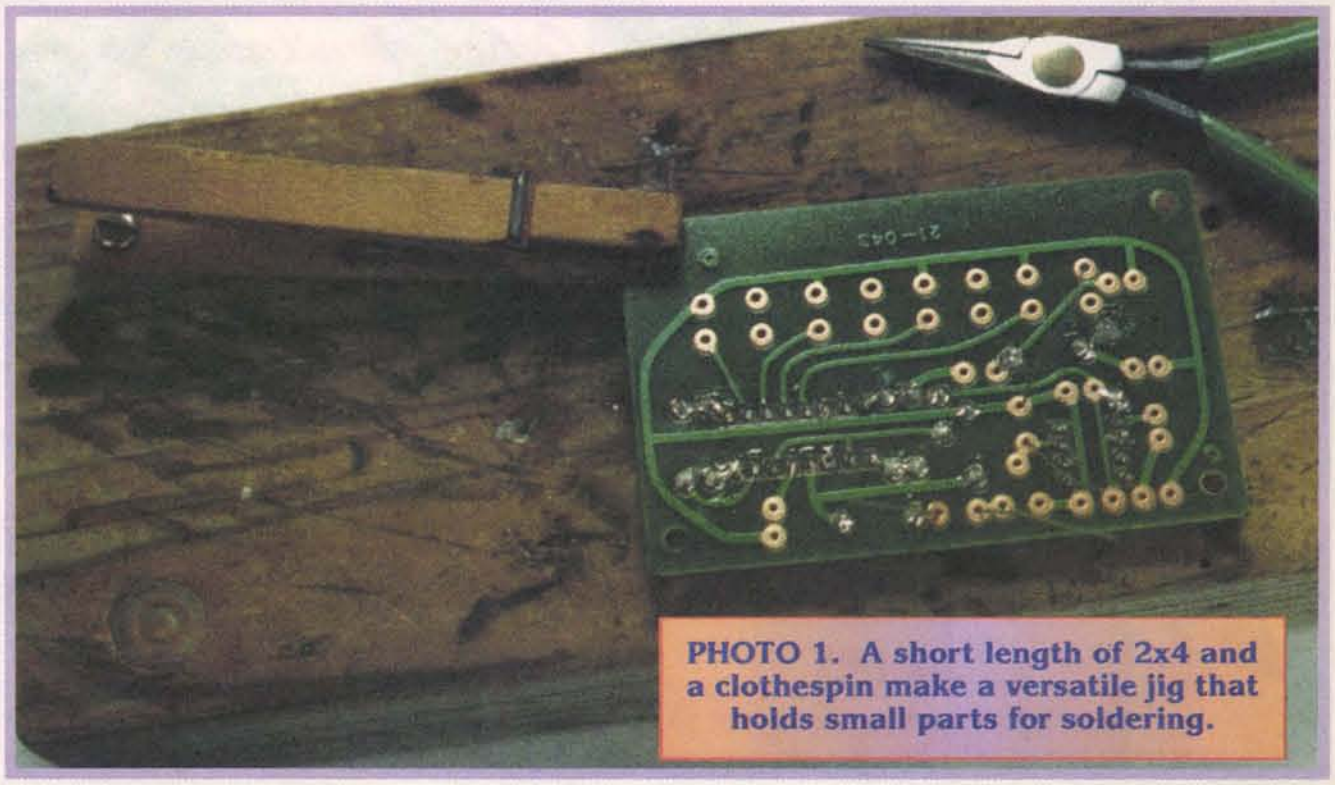

PHOTO 1. A short length of 2x4 and a clothespin make a versatile jig that holds small parts for soldering.

Voice Changer

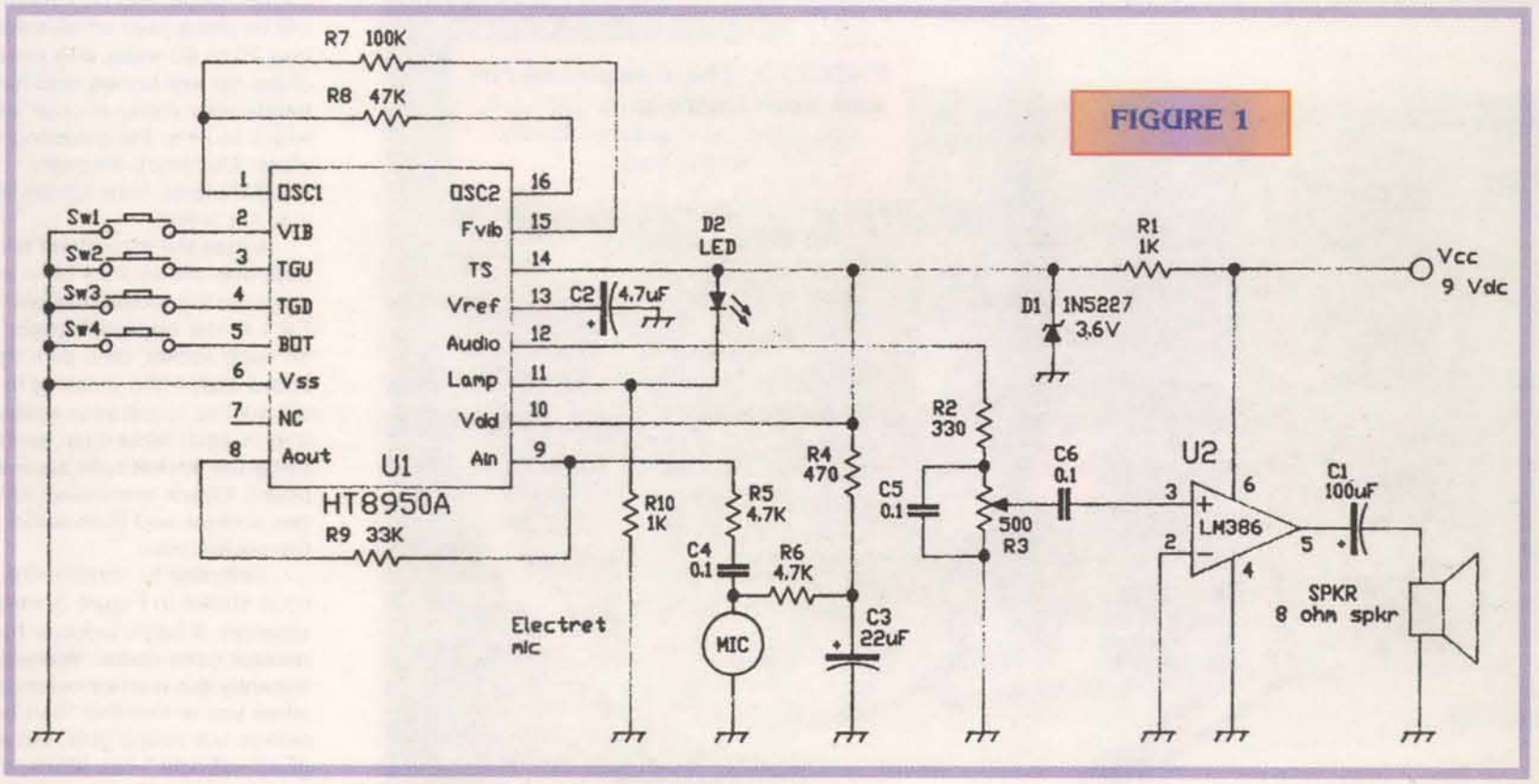

FIGURE 1

put volume is, of course, controlled by pot R3. The LM386 drives an eight-ohm speaker via coupling capacitor C1.

Vibrato

An output voice will be generated with a vibrato effect when the VIB pin is triggered, regardless of what state the system is in. The vibrato pin toggles the vibrato state. That is to say, when a voice output is playing with vibrato effect, this effect can be eliminated by retriggering the VIB input. The rate of vibrato effect can be changed by changing the value of resistor R7.

Voice Modulation

The HT8950A provides eight-bit analog-to-digital (A/D) and eight-bit digital-to-analog (D/A) converters with a sampling rate of 8 KHz, ensuring voice output of high quality with a high signal-to-noise (S/N) ratio. The large scale integrated (LSI) circuit includes seven steps to shift the frequency of the input signal. The frequency steps are illustrated in the following table:

0	Down3	2/3
1	Down2	4/5
2	Down1	8/9
3	Normal	1
4	Up1	4/3
5	Up2	8/5
6	Up3	2
7	Robot	

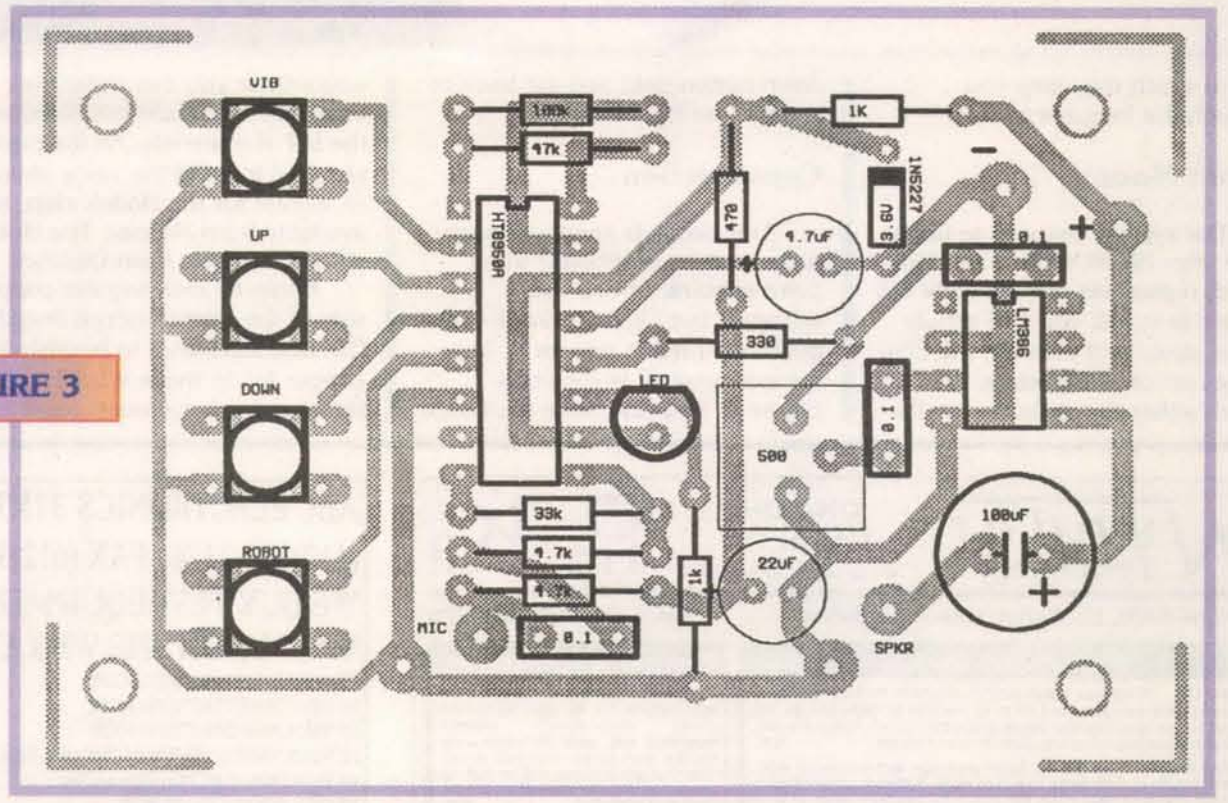

FIGURE 3

Power Up

The chip powers up in robot mode. The TGD (down) pin steps the frequency in the direction Down1, Down2, Down3. The TGU (up) pin steps the frequency in the direction Up1, Up2, Up3. So after power-up, if you assert the TGU (up) input by pressing the UP button, you step to Down3. Simple, huh?! The numbers listed in the far right column of the preceding table give you the "speed ratio" that indicates, for example, that Down3 provides an output frequency that is two-thirds of the input frequency.

Either input TGD or TGU can get you to any frequency setting. The only difference between "up" and "down" is the direc-

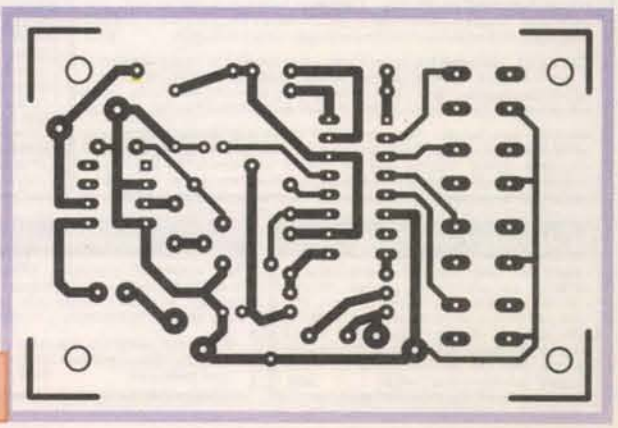

FIGURE 2

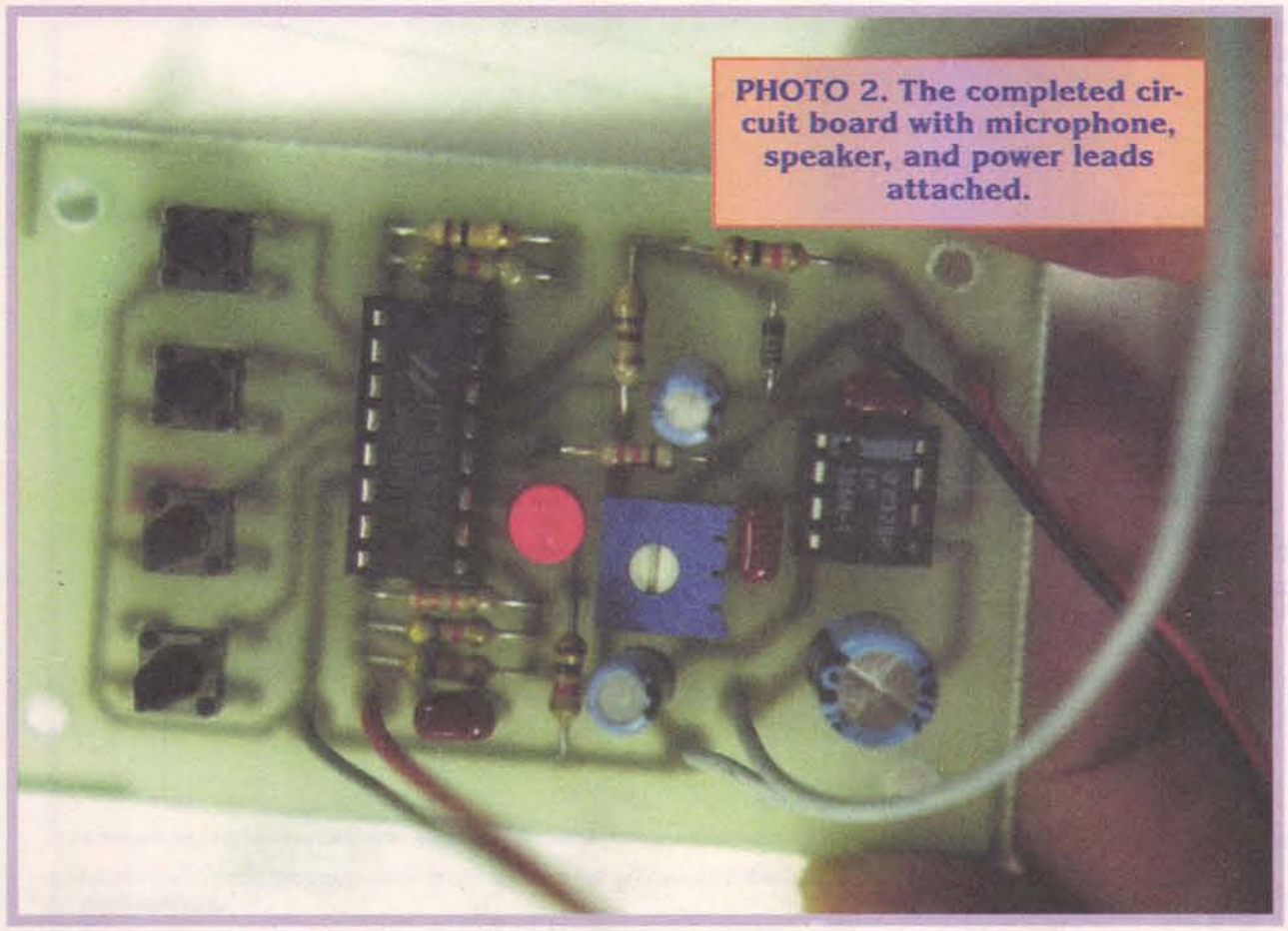

PHOTO 2. The completed circuit board with microphone, speaker, and power leads attached.

tion in which they step you through the frequency table.

Robot Mode

The system changes to Robot state after the ROBOT pin is triggered, regardless of what state the system is in. Or, you can simply power down and then up; the chip comes up on Robot state, or punch either the up button or the down button until you get back to state 7, the Robot state.

Construction

The circuit is simple enough to be built on perf-board wired point-to-point, or even wire-wrapped, but I like a printed circuit board, so I made one for it. The foil side artwork is shown in Figure 2. You can make the board yourself, or you can order the board from the address given with the bill of materials. All the parts required to build the voice changer, except for the Holtek chip, are available from Mouser. The Holtek chip is available from Digi-Key.

Begin by cleaning the copper side of the printed circuit board. Use fine steel wool to burnish the copper foil to make it bright and shiny and remove resist residue, copper oxide, etc. Of course you will be using your small soldering iron 25 to 40 watts with pencil or chisel tip well tinned, and have handy your damp sponge with which to keep the soldering tip clean. Use small diameter (0.031") rosin core solder; 60/40 lead/tin is fine.

Install the IC sockets taking note that the sockets have an indicator for the location of pin 1. Tack-solder opposite corner pins on each socket, then pick up the board and, while pressing in on the socket, touch your soldering iron to each tacked pin and thus press the socket tight against the board. Check orientation of the two sockets and then solder all of the socket pins.

Referring to component locations shown in Figure 3, install the resistors. It helps to know the resistor color codes. You will recall instantly the resistor color codes when you remember "bad boys ravage our young girls, but violet gives willingly." Yes, black, brown, red, orange, yellow, green, blue, violet, gray, white, for 0, 1, 2, 3, 4, 5, 6, 7, 8, 9. (They're not allowed to teach stuff like that anymore, so be thankful that there are still some of us old timers around to pass along important electronic lore of the past.) All resistors are mounted on 0.5" centers, so you can use your bending tool (Jameco part number 106884) to form the leads.

It is good practice to insert the resistors such that the color codes read consistently such as left-to-

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Phone Line Transponder

7 individual output pins are controlled with buttons 1-7 on your touch-tone phone. Automatically answers telephone and waits for commands. Monitor room noises with built in mic. "Dial-Out" pin instructs unit to pick up phone and dial user entered number(s). Password protected. **$49**

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HP 5370A 100MHZ U.T.I. COUNTER	$400.00	LECROY 7200 400MHZ O-SCOPE	$1000.00
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HP 8350B SWEEP OSCILLATOR MAINFRAME	$2000.00	TEK 496P 1KHZ-1.8GHZ SPEC.ANALYZER	$3500.00
HP 3437A 3.5DIGIT SYSTEM VOLT METER	$250.00	TEK 1240 LOGIC ANALYZER	$750.00
HP 3455A DIGITAL MULTIMETER	$250.00	TEK TDS320 100MHZ DIGITAL O-SCOPE	$1400.00
HP 3456A DIGITAL MULTIMETER	$400.00	TEK 11401A 500MHZ PROG.O-SCOPE FRAME	$750.00
HP 3336C SYNTHESIZER/LEVEL GENERATOR	$800.00	TEK 7854 400MHZ OSCILLOSCOPE FRAME	$500.00
HP 3325A SYNTHESIZER/FUNCTION GENERATOR	$1000.00	TEK 7904 400MHZ OSCILLOSCOPE FRAME	$250.00
HP 5335A 200MHZ COUNTER	$600.00	TEK 7A26 200MHZ VERTICAL PLUG	$75.00
HP 8165A PROGRAMMABLE SIGNAL SOURCE	$1100.00	TEK 7A24 400MHZ VERTICAL PLUG	$150.00
HP 8558B/181 100K-1500MHZ SPECTRUM ANALYZER	$1000.00	TEK 7B80 400MHZ TIME BASE	$75.00
HP 8559B/183 10MHZ-21GHZ SPECTRUM ANALYZER	$3000.00	TEK 7B92A 500MHZ DUAL TIME BASE	$125.00
HP 1740A 100MHZ OSCILLOSCOPE	$250.00	TEK 7S12 SAMPLING PLUG	$250.00
HP 6034A 60VDC-10A POWER SUPPLY	$750.00	TEK 7L14 10KHZ-1.8GHZ SPEC. ANALYZER	$1000.00
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Analog voice changers

Analog voice scramblers and voice changers are based on the same building blocks, mixers, and local oscillators. A voice scrambler and a voice changer are diagrammed side-by-side in Figure 4 to show how similar they are. Each system has a microphone, two mixers, two local oscillators, a transmission line, and a speaker.

In the voice scrambler, the local oscillators are at separate ends of the line; one in the transmitter and one in the receiver, and they oscillate at the same frequency. In the voice changer, both local oscillators are in the transmitter and they operate at different frequencies; the difference being the amount by which voices are to be shifted.

The device that audio engineers call their "mixer" is not the device we are dealing with here. The audio engineer's mixer is really an adder. The mixer we need here is the kind used by radio engineers; it is really a multiplier.

If you add signal s1 = cos f1 to signal s2 = cos f2, you just get cos f1 + cos f2. The signals remain intact and, in fact, you can isolate and extract either signal with a band-pass filter. But if you multiply cos f1 times cos f2, you create an entirely different signal. In your trigonometry textbook, you will find the following two identities (they are called identities because they hold for all values of A and B):

cos (A+B) = cos A cos B - sin A sin B
cos A cos B + sin A sin B

If we add these two identities together, we get

cos(A+B) + cos(A-B) = 2 cos A cos B

or

cos A cos B =
0.5 cos(A+B) + 0.5 cos(A-B)

Applying this result to our case, we get:

cos f1 cos f2 =
0.5 cos(f1+f2) + 0.5 cos(f1-f2)

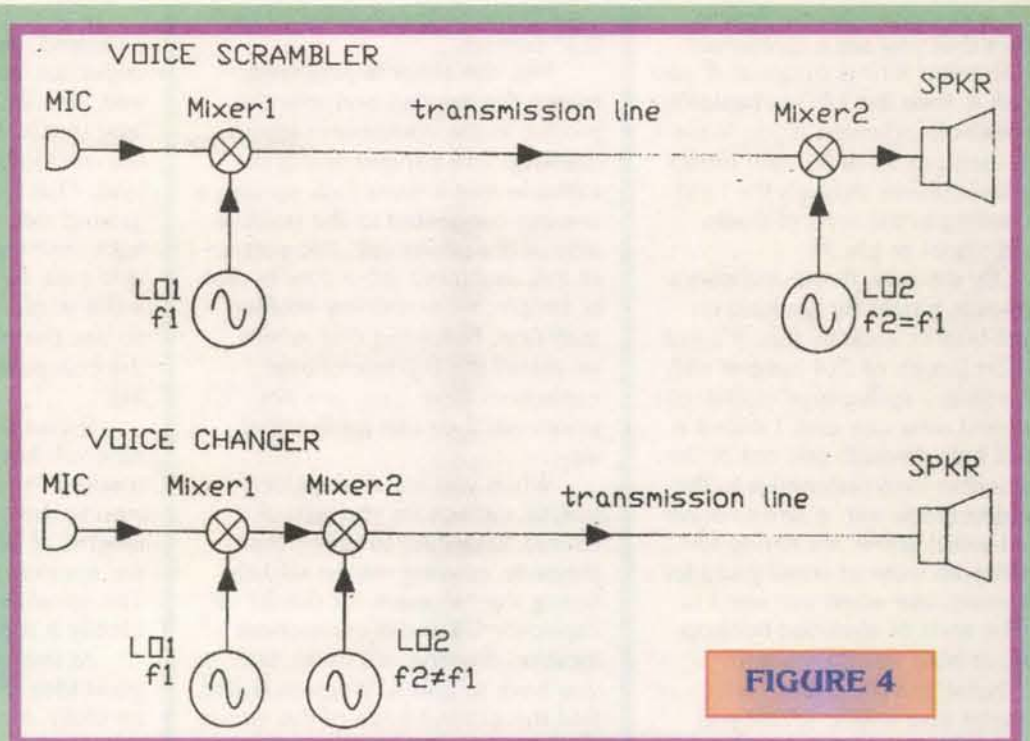

FIGURE 4

In other words, when you multiply signal s1 by signal s2, what you get are two new signals: one oscillating at the sum of the original frequencies, and the other oscillating at the difference of the two original frequencies; with amplitude reduced to half its original value.

In this ideal mixer, the two original frequencies disappear entirely. In a real mixer, of course, things are not quite this tidy.

But this mixer is doing something else that does not at first meet the eye; it is inverting the spectrum of the input signal. If we use a low-pass filter to save only the lower sideband of what comes out of the mixer, we will find that what goes in low comes out high, and vice versa.

To understand this "sideband" lingo, it is advisable to draw a diagram of what is actually going on here. In Figure 5, we have plotted a band of audio input frequencies extending from 300 Hz up to 3000 Hz. The amplitudes are not important; we show a linear spread of frequencies just to help see which end of the spectrum is which. We set up our local oscillator to run at say, 3500 Hz. What comes out of the mixer is a lower sideband containing all of the difference frequencies (f1-f2), and an upper sideband containing all of the summation frequencies (f1+f2).

On the lower sideband, what goes in at 300 Hz comes out at 3200 Hz; what goes in at 3000 Hz comes out at 500 Hz. In other words, the spectrum has been inverted; what was low is now high, what was high is now low. The frequency inversion is what scrambles your voice. We put the output of the mixer through a low-pass filter to save only this lower sideband and, in this way, we have turned the spectrum end-for-end. Garbled indeed.

To recover the original voice at the receiver, we run the garbled signal through another mixer identical to the first one; with its local oscillator set to the same 3500 Hz frequency. Again we save only the lower sideband. What now goes in at 3200 Hz comes out at 300 Hz, and what goes in at 500 Hz comes out at 3000 Hz. In other words, we have inverted the inverted spectrum and everything is back to normal.

What will happen if you run the second local oscillator at a frequency different from the first local oscillator? What will happen is, you will have invented the voice changer. Suppose we run the second local oscillator at 3600 Hz, or 100 Hz above the frequency of the first local oscillator. What goes in now at 3200 Hz will come out at 400 Hz, and what goes in at 500 Hz will come out at 3100 Hz. But the 3200 Hz signal is really our original 300 Hz signal in disguise, so what we have done is shifted the original 300 Hz signal up to 400 Hz.

Similarly, the 500 Hz signal is our original 3000 Hz in disguise, so overall what we have is our original spectrum shifted up in frequency by 100 Hz; we have a voice changer.

The second mixer inverts the inverted spectrum output from the first mixer, so your voice in no longer garbled, it is just shifted up in frequency. The diagram in Figure 5 shows the amplitude dropping by one half at each mixer in accordance with our earlier mathematical analysis but, in an actual system, one or more amplifiers — probably integrated into the low-pass filters — would be used to maintain signal volume.

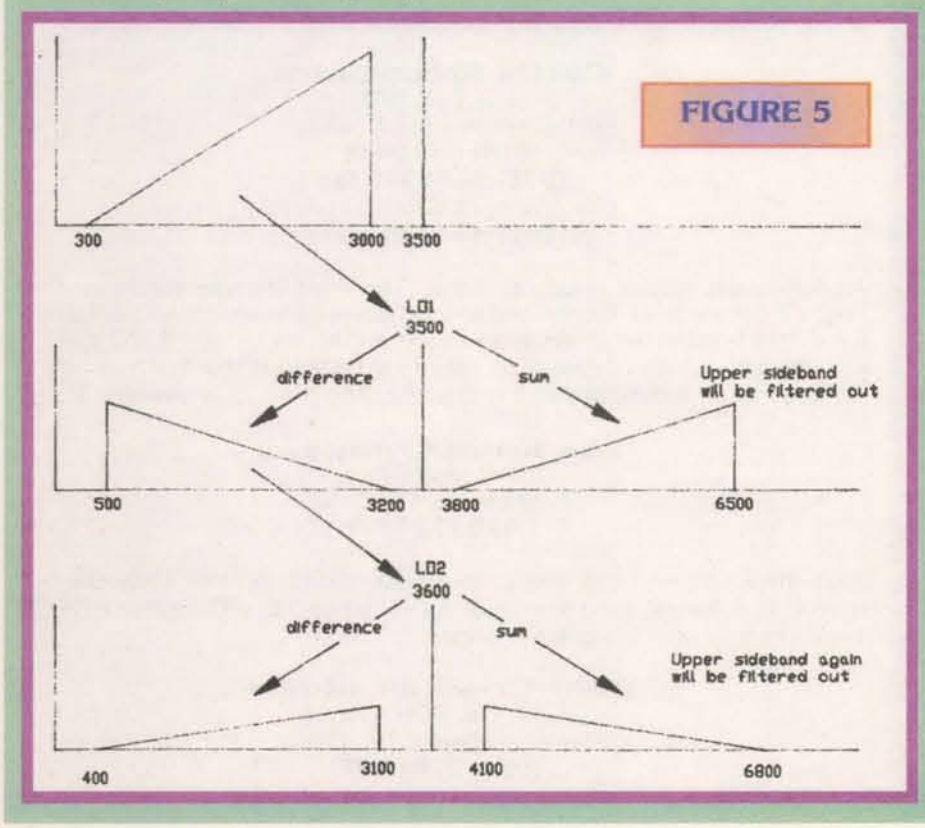

FIGURE 5

right and top-to-bottom. Well, it shows that you are a craftsman.

Resistor R10 is optional. If you install it, then the LED is basically a power-on indicator. If you leave it out, then pin 11 of IC1 will modulate the current through the LED according to the level of audio input signal at pin 9.

By the way, Photo 1 shows a jig that is handy for working on small boards such as this. It's just a short length of 2x4 lumber with an ordinary spring-type clothespin fastened near one end. I drilled a small hole through one ear of the clothespin then fastened it to the wooden block with a small round-head wood screw. It's handy for holding all sorts of small parts for soldering, like when you need to tin the ends of stranded hookup wire, or hold this little board.

Install the trimmer potentiometer and solder. When you bend the leads of the zener diode, hold the lead with your needlenose pliers, grabbing the lead between the glass package and the bending place. That way you won't crack the glass. But you have to hold really close to the case because the diode goes in on 0.3" centers.

Yes, the zener is polarized; match the banded end with the picture in the component layout drawing. The banded end is the cathode and it must look up into a resistor connected to the positive side of the power rail. The pattern of this assembly procedure is pretty simple: we install low profile stuff first. Following that advice, we install the 0.1 microFarad capacitors next. They are not polarized; they can go in either way.

When you install the electrolytic capacitors you will, of course, take care to orient them properly, cussing me for slightly hiding the "+" mark for the 22 uF capacitor C3 in the component location drawing. It's there, but you have to find it. When in doubt, find the ground trace of the circuit board and put the "-" lead there.

The push-button switches will fit down against the board if you push them in. If you don't want to push that hard, then you may want to open up the mounting holes slightly.

The electret microphone is polarized, like an electrolytic capacitor, but it isn't marked as well, so look it over carefully. The lead that is attached to the case of the microphone is the negative lead. That lead attaches to the ground side of your circuit. The light emitting diode also is a polarized part. Its cathode is marked by a flat portion of the plastic case, so use the orientation shown in the component placement drawing.

Solder the red lead of the nine-volt battery clip to the pad marked "+" and solder the black lead to the "-" pad. Use two lengths of hookup wire to connect the speaker to the "SPKR" pads. The speaker is not polarized; electrically it is just a coil of wire.

At this point, it would be a good idea to look your work over carefully. Measure the resistance across the nine-volt battery clip. No, it should not be zero. The assembled circuit in Photo 2 measured just a little over 6000 ohms across the battery clip.

If you have a small resistance, or no resistance, something is upsidedown, like maybe the zener, or you've got a solder bridge somewhere.

If things look okay, install the two ICs following the orientation indicated in the component placement drawing. Both are installed with pin 1 toward the top of the board. Well, now you're ready to connect a nine-volt battery and "tune for smoke," zero smoke being the preferred value.

Options

As we indicated earlier, you don't really need four push buttons to step through the available modulations. A single push-on push-off power switch and one momentary push button connected to the TGU pin, for example, would allow you to get to any modulation the HT8950A provides. To get to robot mode, power down and then up; the circuit powers up in robot mode. Punching the up-button can then step you in circular fashion through all the other modulations. So, depending on how you decide to package your voice changer, you may find it easier to provide just a power switch and one push button connected to either TGU or TGD.

In place of the eight-ohm speaker, you may want to install a phone jack so that you can connect the audio output to headphones. The 32-ohm headphones that I tried worked fine. NV

PHOTO 3. This voice changer from Taiwan is also based on the HT8950; it has the microphone topside and the speaker on the bottom.

You Have Alternatives ...

After designing my own board for this kit, I got on the Internet and discovered an almost identical kit imported from Taiwan; available from Carl's Electronics. Sharp-eyed readers may notice that the circuit board being worked on in Photo 1 is the PC board from the Taiwan kit.

Carl's Electronics
P.O. Box 722
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(978) 840-8834
(978) 840-6172 fax
http://www.electronickits.com
carlton@mail.ultranet.com

A ready-made version is also available. The voice changer shown in Photo 3 comes from Taiwan and is built around a bare HT8950 unpackaged chip bonded out directly onto pads on the circuit board and then covered with a blob of epoxy; an assembly technique that really carries surface mount technology to the extreme. The product is available from:

The Edge Company
P.O. Box 826
Brattleboro, VT 05302
1-800-732-9976

Alas, there's more. From China, an AK-700 style telephone (available from **C & S Sales, Inc.; see their ad on page 75**) with built-in HT8950 voice changer chip is available from:

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